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# Exploring the Relationship between Childhood Obesity and Proximity to the Coast: A Rural/Urban Perspective

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## **Highlights**

This study examines the relationship between childhood obesity and coastal proximity.

Results indicate that childhood obesity prevalence is lower in coastal England.

However this relationship is apparent outside of, but not within, urban conurbations.

Future policy initiatives could focus on improving coastal access for children.

## ABSTRACT

Childhood obesity is one of the 21<sup>st</sup> century's most serious global health challenges. Research suggests that better access to 'greenspace' (e.g. parks) may encourage physical activity and reduce the risk of obesity amongst children. We extend earlier work by considering childhood obesity in relation to proximity to the coast, using data from England's National Child Measurement Programme. Results suggest that although the overall prevalence of childhood obesity is slightly lower at the coast (-0.68 percentage points comparing <1km to >20km,  $p < 0.001$ ), the relationship depends on area type. Specifically, although a coastal proximity gradient (lower obesity rates nearer the coast) was found for rural areas and smaller cities and towns, it was not present among large urban conurbations (interaction  $p$ -value  $< 0.001$ ). Coastal environments and access to them are changing in many areas, and research to explore potential impacts on child health is warranted.

**Keywords:** coast; obesity; child; rural; urban

### 1. Introduction

The World Health Organisation (WHO) (2009) considers childhood obesity to be one of the greatest contemporary global challenges. The National Health Service (NHS) (2008) estimates that in the UK there are currently one million children under the age of 16 years who are obese. Without intervention, they warn that 90% of the UK's children could be overweight by 2050 (NHS, 2008). Childhood obesity has been shown to lower children's quality of life, to cause serious health consequences (Waters, 2011; Tsiros et al., 2009) and is also a highly influential determinant of adult obesity (Biro and Wein, 2010; Flodmark et al. 2004; Reilly and McDowell, 2003). Reducing childhood obesity has therefore become a key target for the UK government (Department of Health, 2011).

Childhood obesity is influenced by a complex web of factors ranging from genetics to the sociocultural environment (Foresight Programme, 2007). However, when considering the rapid increase in obesity over the last 30 years, an overriding effect of the environment (broadly defined) is suggested, since changes have surpassed the time-scale of genetic evolution (Thigpen, 2004). One of the most influential environmental predictors of childhood obesity is socio-economic status. For instance,

the National Obesity Observatory (NOO) (2012) report that children from the most deprived areas in England were almost twice as likely to be obese than children from the least deprived areas.

Regional and urban/rural differences in childhood obesity prevalence have also been reported. For instance, the Marmot (2010) Review suggests a North/South divide in England, but found the biggest inequalities in childhood obesity to be within London. Within the debate regarding whether urban or rural environments are most conducive to obesity, research outcomes have remained ambiguous (Thigpen, 2004). In the UK, the National Child Measurement Programme (NCMP) outcomes from 2012/13, found that children from urban areas had higher levels of obesity than their rural counterparts (Health and Social Care Information Centre (HSCIC) 2013). Ridler et al. (2011) however, suggest that the urban/rural divide in obesity is indistinct. They argue that although urban areas are more conducive to childhood obesity, they found that some affluent urban communities had the lowest levels of childhood obesity in England.

In contemporary research and policy, physical environmental influences on childhood obesity have received considerable attention (e.g. Edwards et al., 2010; Dunton et al., 2009; Evans et al., 2012), particularly regarding active environments (Wheeler et al., 2010; Park et al., 2011; Kyttä et al., 2012). Research has typically focused on how greenspace (e.g. parks, natural woodland or grassland) may promote physical activity and thus, potentially deter the development of obesity (Bell et al., 2008; Park et al., 2011). For instance, Coombes et al. (2010), Roemmich et al. (2006), and Veitch (2005) conducted studies examining this hypothesised relationship within the UK, US and Australia respectively. They suggested that children living in closer proximity to parks or with access to gardens were more likely to partake in regular physical activity. In contrast, Wheeler et al.'s (2010) study of children's physical activity using GPS tracking and accelerometers in Bristol, UK, reported that most physical activity amongst children is not conducted in greenspace, but rather in non-green urban areas. However, they found that when children, particularly boys, played in greenspace, activity was more intense. This gender difference is consistent with Sanders et al.'s (2015a,b) longitudinal study in Australia, which suggested that increased neighbourhood greenspace is predictive of lower body mass index (BMI) and higher moderate to vigorous physical activity only

in boys, but not girls. How access to greenspace in turn affects childhood (or boys') obesity is disputed. For instance, Potestio et al. (2009) found that proximity to community parks in Canada was not associated with reduced levels of childhood obesity. However, Cetateanu and Jones (2014) analysed NCMP data and found that childhood obesity prevalence was inversely associated with greater greenspace density in England.

An emerging body of research, much of it from Australia, has found similar health benefits linking proximity to bluespace (i.e. aquatic environments such as rivers, lakes and the coast) and physical activity (e.g. McCormack et al., 2008; Ball et al., 2007). One of the most influential studies was conducted by Bauman et al. (1999). They found that individuals residing within coastal postcodes in Australia were 38% more likely to undertake vigorous exercise, 27% more likely to partake in levels of physical activity adequate for health and 23% less likely to behave sedentarily, than individuals residing outside coastal postcodes. They named this phenomenon the 'coastal effect' (Bauman et al., 1999, 322). However, these findings are based on self-reported survey data, therefore they could be influenced by self-reporting bias. Furthermore, a study in China found that children residing in Northern coastal regions had the highest obesity prevalence. However they attribute this association to affluence in the coastal areas, linking with the fast development of China and the increased nutrition available for children (Ji and Cheng, 2009).

The relationship between physical activity, health and coastal proximity is of particular importance in England since it is bounded by approximately 4000km of coastline (Department for Environment, Food and Rural Affairs, 2007). Studies regarding the 'coastal effect' for the UK are limited, but are suggestive of a similar outcome. In a qualitative study, Ashbullby et al. (2013) found that in the UK beaches provided an opportunity for families to engage collectively in physical activity. Furthermore, a cross-sectional study based on interviews with over 180,000 residents of England, indicated that those living closer to the coast were more likely to self-report achieving recommended physical activity levels, and that this was mediated by visits to the coast (White et al., 2014). Furthermore Elliott et al. (2015) report that overall adult energy expenditure is greater when visiting coastal environments, in comparison to the countryside or urban greenspace, due to the relatively longer duration of the visit. These are set in the context of a study by

Wheeler et al. (2012) indicating that self-reported good general health was higher with proximity to the coast and that this effect was stronger for urban and more deprived communities, hypothesising that this could be attributed to greater opportunities for physical activity and stress reduction.

However, both physical and socio-economic access have been shown to influence the degree to which a community benefits from the resources of natural environments, and Natural England (2011) suggest that perceived access to natural environments is often more pervasive than physical proximity. For instance, Babey et al. (2007) and Taylor and Lou (2011) in the US found that for children living in deprived neighbourhoods, perceptions of whether greenspace was considered safe determined the likelihood of the associated physical activity within these areas. Furthermore Ashbullby et al. (2013) found that car availability and the cost of parking was a key barrier to visiting the seaside. In addition, public transport and opportunities for active travel may be limited within rural settings (Pateman, 2011).

Using secondary data from the NCMP, this paper builds upon Cetateanu and Jones' (2014) childhood obesity and greenspace study and the emerging bluespace and health literature to examine the relationship between childhood obesity and proximity to the coast. Additionally, since the NCMP outcomes from 2012/13 found that children from urban areas, in general, experienced higher levels of obesity than their rural counterparts (HSCIC, 2013) and Wheeler et al. (2012) found a stronger effect of coastal proximity on health and wellbeing in urban areas, the relationship is tested for modification by urban/rural location.

## **2. Methods**

The availability of a relevant, small-area dataset (from the NCMP) provided the opportunity for a cross-sectional ecological approach based on a very large sample, with which to examine the association between childhood obesity and coastal proximity.

### *2.1 Study Population and Geographical Scale*

The NCMP is run annually by the HSCIC and measures the weight and height of children between the ages of 4-5 and 10-11 years in England. The NCMP dataset is the most representative nation-wide dataset regarding childhood obesity prevalence,

with 93% of children per eligible state school taking part in 2012/13 (HSCIC, 2014). The study population ( $n = 1,475,617$ ) were children aged between 10-11 years, with childhood obesity prevalence ( $\text{BMI} \geq 95^{\text{th}}$  percentile) as the outcome. The NOO (2014) combined the latest three years of NCMP data- 2010/11 ( $n = 495,353$ ), 2011/12 ( $n = 491,118$ ) and 2012/13 ( $n = 489,146$ ) - thereby increasing the number of child measurements per area, which has been shown to produce more statistically significant variances in obesity prevalence (Dinsdale and Ridler, 2011).

NCMP data were available in aggregate form for 2001 Census Middle-Layer Super Output Areas (MSOA), and these were therefore used as the geographical unit of analysis. MSOAs have been argued to represent the most appropriate scale for robust small-area estimates for the NCMP dataset (Dinsdale and Ridler, 2011). In England there are a total of 6781 MSOAs (at 2001), with a mean population of 7200, a minimum population of 5000 and a maximum population of 15,000 (Office for National Statistics (ONS) 2011a). MSOAs, unlike electoral wards/divisions, are designed to have approximately consistent population size, and are generally not subject to temporal boundary changes. Furthermore, they group socially similar households and consider local infrastructure. Their comparability and stability are therefore beneficial for this type of analysis (ONS, 2013).

## *2.2 Primary Exposure Variable*

The primary exposure variable for this study was coastal proximity. For the purpose of this paper, coastal proximity was simply measured as the Euclidean distance from the coast, as data on walkability and access, at the household level, was unavailable. Since there is no official boundary for when the coastline becomes estuary, we used Wheeler et al.'s (2012) approach of capping estuaries at a width of approximately 1km. Since analysis is based on MSOA level data, distance from the coast was measured by calculating the linear distance from the MSOA 2001 population weighted centroid, to the nearest coastal point using QGIS (Quantum GIS Development Team, 2014). Using the population weighted centroid is a best-fit point representing the spatial distribution of the population within the MSOA at the time of the 2001 census (ONS, 2011b).

The MSOA distance from the coast variable was not normally distributed (Table 1). In order to avoid the potential distortion of regression outcomes resulting from a



highly skewed continuous variable (Osborne and Waters, 2002), and reflecting White et al. (2014), coastal proximity was categorised into four distance bands - 0-1km, >1-5km, >5-20km, and >20km. White et al. (2014) used these thresholds to approximate geographical accessibility, and thereby the frequency of potential exposure to coastal environments. For instance, the category of 0-1km could infer walking distance, >1-5km may make regular visits feasible, >5-20km could make access less frequent, yet allow for weekend visits and >20km may make regular access improbable (Wheeler et al. 2012). Importantly, White et al., (2014) found strong support for coastal visit frequency using these distance bands (e.g. those living <1km from the coast were 15 times as likely to have visited in the last week compared to those living >20km away). It should be noted, however, that White et al. (2014) examined a sample of individuals aged 16 and over, and the distance measure was based on smaller areal units (LSOA). However this study offered the most appropriate guidance available for selection of distance categories for the current UK based analyses.

### *2.3 Potential Confounders*

Covariates were included to control for potential confounding in the multiple regression model (Table 1). Rural/urban differences were controlled for since childhood obesity has been shown to differ between urban and rural locations (HSCIC, 2013; Ridler et al., 2011) and since Wheeler et al. (2012) found a stronger effect of coastal proximity on health and wellbeing in urban areas. The MSOA classification consists of four morphology codes – urban conurbation, urban city and town, rural town and fringe and rural village and dispersed - and a population density scale of ‘sparse’ or ‘not sparse’ is applied (Bibby and Brindley, 2013). However, since the ‘sparse’ category of MSOA is rare, it was decided that the physical morphology of the area would be the main focus within this report. Since a very low number of MSOAs (4) in the most rural class were within the 0-1km coastal category, the two rural classes were aggregated. A similar approach to urban/rural categorisation has been used in previous relevant studies (Mitchell and Popham, 2007; Wheeler et al., 2012), although these were based on higher resolution geographies.

**Table 1:** Outcome and Predictor Variables for the Relationship between Childhood Obesity and Coastal Proximity

Variable	Data Source	Mean	Standard Deviation	Min	Max	No missing
<b>Outcome variable</b>						
Percentage of obese children aged between 10-11 years	HSCIC <sup>a</sup>	18.61	5.19	0.00	38.69	57
<b>Exposure variable</b>						
Proximity to the coast (km)	Own analysis	40.25	29.70	0.05	110.95	0
<b>Potential confounders</b>						
Index of multiple deprivation (IMD), 2010	DCLG <sup>b</sup>	21.59	13.55	2.01	77.43	0
Percentage of greenspace, 2005	DSI <sup>c</sup>	51.35	27.98	1.27	98.58	0
Percentage of the population aged between 10-14 years, 2011	Census <sup>d</sup>	5.83	1.13	0.83	11.54	141
Percentage of the population of not white ethnicity, 2011	Census <sup>d</sup>	13.42	17.80	0.43	94.37	141
Urban/rural classification, 2011 (categorical)	ONS <sup>e</sup>	n/a	n/a	n/a	n/a	141

a Health and Social Care Information Centre, 2014, NCMP (2010/11-2012/13): <http://www.noo.org.uk/NCMP>; data for 57 MSOAs suppressed to avoid disclosure

b Department for Communities and Local Government, 2010: <https://www.gov.uk/government/publications/english-indices-of-deprivation-2010>

c Data and Statistics Infrastructure Division, 2005: <http://www.neighbourhood.statistics.gov.uk/dissemination>

d Nomisweb, 2011 Census: Aggregate data. <https://www.nomisweb.co.uk/>

e Office for National Statistics, 2011: <https://geoportal.statistics.gov.uk/geoportal/catalog>

The percentage of greenspace (area density) was included as a potential confounder due to its association with childhood obesity (Cetateanu and Jones, 2014; Coombes et al., 2010). This variable is not normally distributed and was therefore categorised into quintiles (Wheeler et al., 2012). Other potential cofounders included the Index of Multiple Deprivation (2010), due to the strong relationship between childhood obesity and socioeconomic status (NOO, 2012; Reisch and Gwozdz, 2011) and since, both Wheeler et al. (2012) and Mitchell and Popham (2007) found that the health benefits derived from access to natural environments, such as the coast or greenspace, were greater amongst the most deprived populations. The percentage of the population

aged between 10 and 14 years was also included, since Salvy et al. (2012) found that the prevalence of children of a similar age group in an area can promote social networking and thereby encourage physical activity through play. Finally, the percentage of the population of non-white ethnicity was considered, as childhood obesity has been shown to differ by ethnicity (Ridler et al., 2009; Gattineau and Mathrani, 2011). Since the two census variables and the urban/rural indicator were for 2011 MSA boundaries, these were only merged into the dataset where the MSA was unchanged between 2001 and 2011. This resulted in a small number of areas (141 of 6781 MSAs, including 2.3% of all measured children) being excluded from analyses.

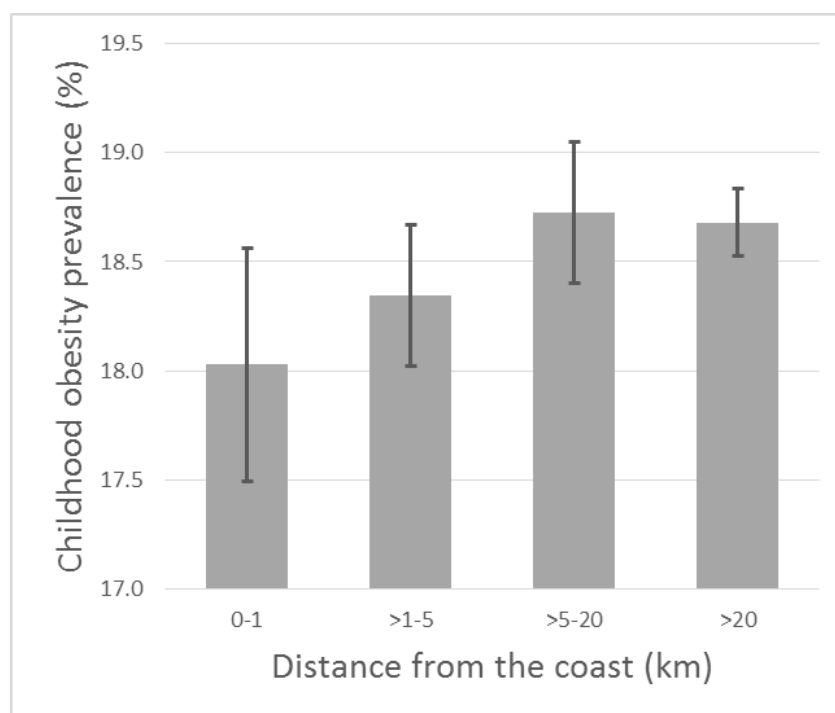
#### *2.4 Statistical analysis*

Regression analyses were run using Stata 13 (StataCorp, CollegeStation, TX) and subsequently stratified by urban/rural category. 'Dummy' variables were created for the three categorical variables, namely proximity to the coast, percentage of greenspace quintile and the urban/rural classification (Skrivanek, 2009). Models were checked for normality, linearity, heteroskedasticity, multicollinearity, and signs of extreme outliers.

### **3. Results**

#### *3.1 The relationship between childhood obesity and coastal proximity*

The NCMP and coastal proximity data were first explored using simple descriptive statistics; Figure 1 plots mean obesity prevalence by coastal proximity. Initial assessment of the association between childhood obesity and coastal proximity suggests that the mean childhood obesity prevalence is lowest 0-1 km from the coast at 18.03%. The prevalence then gradually rises with increasing distance from the coast, reaching a peak of 18.72% between >5-20km from the coast, with a similar value for >20km.



**Figure 1:** Mean childhood obesity by coastal proximity across 6781 MSOAs

The multiple regression model (Table 2) indicates that the shape of this association after adjusting for potential cofounders is not straightforward. The model does suggest that obesity prevalence within 1km of the coast is 0.68 percentage points lower than that for MSOAs >20km inland ( $p=0.003$ ), but also that prevalence is higher in the 5-20km band than further inland ( $p<0.001$ ), and no different in the 1-5km band ( $p=0.102$ ). The prevalence of childhood obesity is 0.68 percentage points lower at 0-1km, in comparison to >20km from the coast after adjustment, but the lack of a proximity gradient makes this association difficult to interpret. The increment in  $R^2$  was calculated for coastal proximity and a value of 0.005,  $p < .001$  was produced. This indicates that coastal proximity only accounts for around 0.5% of the variance in childhood obesity within this model.

Consistent with previous research, the results indicate that childhood obesity is positively associated with deprivation, with residence in the most urbanised areas, and with the percentage of non-white residents. Areas with higher population percentage of 10-14 year olds had lower prevalence of childhood obesity, again consistent with previous evidence. After adjustment, there was no association between area greenspace and childhood obesity.

**Table 2:** Multivariate Regression Model predicting the Relationship between Childhood Obesity and Coastal Proximity

Predictor variable	B	95% CI
<b>Coastal proximity</b>		
>20km <sup>a</sup>	-	-
>5-20km	0.888	(0.618, 1.158)
>1-5km	0.256	(-0.051, 0.563)
0-1km	-0.684	(-1.141, -0.227)
<b>% Greenspace</b>		
Quintile 1 <sup>a</sup>	-	-
Quintile 2	0.460	(0.155, 0.764)
Quintile 3	0.542	(0.225, 0.859)
Quintile 4	0.171	(-0.166, 0.508)
Quintile 5	-0.115	(-0.570, 0.341)
<b>IMD</b>	0.220	(0.212, 0.228)
<b>% Non-white residents</b>	0.046	(0.039, 0.053)
<b>% 10-14 year olds</b>	-0.146	(-0.234, -0.058)
<b>Rural/Urban Classification</b>		
Rural <sup>a</sup>	-	-
Urban city and town	-0.167	(-0.543, 0.209)
Urban conurbation	0.547	(0.124, 0.970)
<b>Constant</b>	13.592	(12.927, 14.257)
<b>R<sup>2</sup></b>	0.47	

**B:** Adjusted non-standardised regression coefficient; **CI:** Confidence intervals; **a** Reference category

### 3.2 Stratification by rural/urban classification

Modification of the association between childhood obesity and coastal proximity by urban/rural category was indicated by a likelihood ratio test ( $p < 0.001$ ). Investigating this interaction, stratified regression models (Table 3) suggested that there was clearer evidence for a coastal proximity gradient among MSOAs in rural areas and smaller towns and cities. For example, amongst rural MSOAs, childhood obesity

prevalence was 2.8% lower within 1km of the coast compared to >20km inland ( $p<0.001$ ). In urban conurbations, results suggested higher prevalence in MSOAs in intermediate proximity categories (1-5km and 5-20km) relative to >20km, but no difference between <1km and >20km, and no trend with proximity.

#### **4. Discussion**

Childhood obesity is a growing concern both within the UK and internationally (WHO, 2012). Not only does obesity impede the quality of life for children, it often permeates into adulthood causing poor health for the individual and high costs to society (Foresight Programme, 2007). The relationship between local natural environments and childhood obesity has received considerable attention, however this literature tends to focus on greenspace (Bell et al., 2008; Park et al., 2011).

In this small-area ecological study, the full regression model indicated a small, but unclear, association with coastal proximity after adjustment, suggesting lower prevalence of childhood obesity in the most proximal coastal MSOAs compared to the most inland, but higher prevalence in intermediate distance bands. There was strong evidence of an interaction with urban/rural category, and stratified models suggested a beneficial association in areas outside of large urban conurbations. In the context of research on coastal environments and other health outcomes, this finding is in contrast to research finding a stronger relationship between self-reported health and coastal proximity in urban, but not rural areas (Wheeler et al., 2012). However, it is consistent with findings of associations between coastal environments and mental health specifically within rural areas of the UK (Alcock et al., 2015).

**Table 3:** Stratification of Multivariate Regression Model predicting the Relationship between Childhood Obesity and Coastal Proximity by Urban/Rural Category

	Rural N= 1184		Urban City and Town N= 2867		Urban Conurbation N= 2535	
Predictor variables	B	95% CI	B	95% CI	B	95% CI
<b>Coastal proximity<sup>a</sup></b>						
>20km	a	-	a	-	a	-
>5-20km	0.166	(-0.330, 0.662)	0.093	(-0.308, 0.494)	2.378	(1.871, 2.885)
>1-5km	-0.592	(-1.271, 0.086)	-0.364	(-0.747, 0.019)	1.46	(0.650, 2.271)
0-1km	-2.786	(-4.089, -1.484)	-1.061	(-1.587, -0.536)	0.596	(-1.242, 2.435)
<b>% Greenspace</b>						
Quintile 1			a	-	a	-
Quintile 2	a*	-	0.652	(0.176, 1.129)	0.324	(-0.079, 0.726)
Quintile 3	0.439	(-2.985, 3.863)	0.591	(0.123, 1.059)	0.463	(0.013, 0.912)
Quintile 4	0.590	(-2.550, 3.730)	0.170	(-0.314, 0.653)	-0.103	(-0.625, 0.419)
Quintile 5	-0.490	(-3.644, 2.663)	0.041	(-0.577, 0.660)	0.575	(-0.579, 1.729)
<b>IMD</b>	0.387	(0.352, 0.422)	0.226	(0.214, 0.238)	0.196	(0.184, 0.207)
<b>% Non-white residents</b>	0.018	(-0.093, 0.129)	0.013	(-0.001, 0.027)	0.064	(0.056, 0.073)
<b>% 10-14 year olds</b>	-0.418	(-0.687, -0.149)	-0.042	(-0.175, 0.090)	-0.128	(-0.260, 0.005)
<b>Constant</b>	13.668	(9.989, 17.348)	13.187	(12.332, 14.041)	14.118	(13.362, 14.874)

**B** Adjusted non-standardised regression coefficient; **CI** Confidence intervals; **a** Reference category; \* No rural MSOAs in lowest national greenspace quintile

White et al (2014) showed a strong proximity gradient for physically active coastal visits in England among adults (see also Elliott et al., 2015) and a similar possibility could be hypothesised for children. Indeed 17% of visits to natural settings in England are with children under 16 years old (contact authors for further details) so it is possible that the adult pattern is replicated in more coastal visits among children living near the coast (outside of urban conurbations).

The explanation for the lack of association in urban conurbations, contrasting with proximity gradients observed for smaller urban and rural areas, can only be speculated upon here. It is possible that for children in larger urban areas, access to coastal environments is more challenging, despite residential proximity. Studies in several countries have suggested that perceptions of safety and independent mobility may be greater for children in more rural areas than in cities (Kytä, 2002; Jones et al., 2000), and these may therefore present barriers to access in urban conurbations. It could also be that the physical characteristics of coastal environments in larger urban areas are less amenable to supporting or promoting children's activity. Cetateanu and Jones (2014) observed an association between this childhood obesity measure and area density of unhealthy food outlets; it is possible that the distribution of these outlets in larger urban areas could negate any benefits of coastal proximity. Lastly, findings in both rural and urban areas are subject to the limitations of the study design and the relatively coarse spatial resolution of the data. These limitations may play a role in the differences found between area types, and these are explored further below.

In terms of the potential importance of these findings, many highly urban conurbations on the English coast do not have good access to the sea, and this may be amenable to improvement through physical and social intervention. As with urban greenspace (Hunter et al., 2015), interventions such as improved transport links, paths and other physical access features, informational resources and signage, local social interventions supporting and encouraging access, and improved quality, maintenance and amenities could potentially serve to capitalise on any health benefits of coastal access. The UK's Marine and Coastal Access Act 2009 sets out to do this by improving access rights for the entire English and Welsh coasts. Under the Act, work is under way to improve physical access, with several sections of coastal path in urban locations being planned and constructed in England (e.g.



Teeside and Portsmouth, Natural England, 2016), and with the Wales Coast Path already complete (Welsh Government, 2016).

#### *4.1 Study Strengths and Limitations*

Due to the cross-sectional nature of this study, causality cannot be ascribed to the associations observed (Aldrich, 1995). Therefore, the study indicates that childhood obesity is associated with coastal proximity, however it cannot be claimed that coastal proximity causes a decrease in childhood obesity. Furthermore, since this study uses area, rather than individual level data, the ecological fallacy may be in operation; the generalisations made between area level/aggregate measures may not necessarily translate to the individual level (Mitchell and Popham, 2007). Also, while we controlled for potential confounding by including area level covariates within the regression model, it is possible that residual confounding explains some or all of the associations observed. As well as the possibility of, for example, incomplete control for socio-economic status, the lower childhood obesity found in this study could also be attributed to healthier food environments near the coast.

A further limitation concerns the method of 'exposure' measurement using the distance from MSOA population weighted centroid to the nearest coastal point, treating the coastline as a homogenous linear feature. This exposure estimation is subject to error, since we are allocating the coastal distance to the MSOA centroid to all children living in that MSOA (whilst in reality there will be variation in proximity within the MSOA). Further, actual road/footpath network distances may differ from the straight-line distances used, and the physical public accessibility of the coast is unknown.

In common with other cross-sectional studies of environmental exposures, it may be argued that the decreased likelihood of childhood obesity with coastal proximity could be biased by the 'healthy migrant effect'. This contends that healthy, active individuals might tend to choose to live in close proximity to green and blue spaces, thereby contributing to lower levels of obesity prevalence by the coast (Wheeler et al., 2012; Stafford et al., 2007; Bauman et al., 1999). In consideration to the positive relationship between health behaviours in parents and their children (Gustafson and Rhodes, 2006), this could mean that more healthy, active children also tend to reside by the coast, thereby reducing the prevalence of childhood obesity in these areas.

Whilst there is no directly relevant longitudinal evidence on the issue at hand, a previous study of coastal proximity, mental health and general health in adults found positive relationships and was able to account for selective migration through its longitudinal study design (White et al., 2013). It is also important to note that evidence concerning the relationship between physical activity and childhood obesity is disputed (Brown et al., 2007). For instance, Metcalf et al.'s (2008) study in the UK indicated that physical activity which exceeds government guidelines was not associated with BMI. In contrast, Edwards et al.'s (2010) study in Leeds found that high levels of physical exercise were associated with lower levels of childhood obesity.

Despite the limitations, this study has several noteworthy strengths. The highly representative NCMP sample that was used included 99% of eligible state schools (Public Health England, 2013), of which the participation rate was 93% (HSCIC, 2014). Furthermore, since the English coastline spans over 4000km (DEFRA, 2007), the study included analysis of a large number of coastal MSOAs (<5km, N=1147). This increases the generalisability of results, as well as making the findings particularly applicable to the English population where access to coastal environments is widely available. In the broader context, while childhood obesity is a complex issue involving individual, societal and environmental determinants, it has been argued that addressing 'obesogenic environments' is a key opportunity for social policy on obesity (Lang and Rayner, 2007).

#### *4.2 Future Research*

This paper represents a preliminary study exploring the relationship between coastal proximity and childhood obesity. Design limitations of the study limit causal inference, but it presents a number of questions and possibilities for future research.

Firstly, similar studies could be conducted using more robust individual and longitudinal study designs. Future studies, ideally using individual-level data, could benefit from more nuanced measures of access, for example using road/path network distance from precise home locations, and differentiation of whether the nearby coastline is actually walkable or open to the public. With more precise location of children's residences and access routes, it would also be valuable to consider finer grading of distances, since access and use may vary with proximity

even within the 1km zone. The types of activities children participate in by the coast could be explored, as well as intervention studies on how physical activity might be encouraged for children using coastal environments. Other research avenues could explore coastal food environments, to investigate diet/physical activity interactions, and further studies could contribute to the explanation of the urban/rural differences found within this study. Natural England are currently implementing a monitoring and evaluation programme to assess the impact of access improvements under the Marine and Coastal Access Act, including measuring volumes of physical activity in affected neighbourhoods, and urban/rural context should be considered. It may be possible to revisit the NCMP data in future years to explore whether the coastal proximity gradient we find for rural and smaller urban areas can also subsequently found in highly urban conurbations after relevant sections of access improvement are complete. Whilst this research is based on the English population, at least 10% of the world's population live within 10 km of the coast (CIESIN, 2012), and it is therefore possible that any benefits could be globally relevant. However, it is likely that relationships with coastal areas vary between places and cultures, and that opportunities differ, but since obesity is a global issue, international research on the potential benefits of coastal activity is warranted.

## **5. Conclusion**

The findings from this study suggest that improved access to the coast for children may help counteract the critical contemporary challenge of childhood obesity, taking advantage of the opportunities natural ecosystems can provide. In common with other studies of health and wellbeing benefits of natural environments, the urban/rural context is likely to be an important consideration. While the relationship was relatively small in magnitude and was not found in urban conurbations, any small potential benefits could be experienced by large populations in coastal countries such as the UK.

If coastal environments are genuinely related to reduced obesity risk, recommendations for the future might include the enhancement of coastal access through schools by increasing the amount of day trips to the coast, and combining physical activity with studies of ecosystems. Some characteristics of coastal environments could be replicated in other locations, such as virtual environments

and artificial beaches (Wheeler et al., 2012). For instance in landlocked Nottingham, UK, a beach is constructed annually in the urban centre throughout the summer months (BBC, 2012). Careful monitoring of childhood physical activity along the new stretches of coastal path currently under development in urban conurbations in England is needed to explore whether improvements in access result in potential health gains.

The opportunities presented by coastal and other natural environments may have an important part to play in creating more healthy environments for children (Foresight Programme, 2007). For this to be achieved, a holistic approach may be necessary, with intervention from the individual to the international policy scale (Lang and Rayner, 2007). However, our global coasts are increasingly being threatened by pollution, unsustainable management and extreme weather events driven by climate change (Wyles et al., 2014; Bowen and Depledge, 2006). It is therefore essential that management of the coast is both effective in improving the experience of visiting the coast, as well as protective of its fragile ecosystems (McEvoy et al., 2008; Depledge and Bird, 2009).

### **Ethical approval**

No ethical approval was required due to use of publically available, aggregate secondary data.

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